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AUTHOR Firestein, Laurie
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ABSTRACT

"ARITHMETIC 400" is the first of the next generation of educational programs designed to encourage thinking about arithmetic problems. Presented in video game format, performance is a measure of correctness, speed, accuracy, and fortune as well. Play presents a challenge to individuals at various skill levels. The program, run on an Apple microcomputer with 64K, is designed for use in elementary, junior, and senior high schools; little or no supervision is required. Now in use in some schools of the Los Angeles Unified School District, the program, with its emphasis upon bigger numbers, decimal and position, does not fall into one to one correspondence with the traditional classroom. Therefore, the history of the traditional classroom is reviewed, stressing those events which have shaped its structure, showing why it has run its course, and why the time for change is now. The use of and reactions to the program in an elementary school setting is then described. It is pointed out that "ARITHMETIC 400" (which sets aside paper and pencil dependency, stressing numbers to remember and think about) is not only a game but also a tool for teaching mathematics and creative thinking. (JN)

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Welby Way Elementary School

23456 WELBY WAY, CANOGA PARK, CALIFORNIA 91307

3635

WILLIAM J. JENNINGS
Superintendent of Schools

KENNETH FIELDS
Principal

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COMPUTER USING EDUCATORS
FOURTH ANNUAL SPRING CONFERENCE

SOUTHERN CALIFORNIA

May 17, 18, 19, 1984

ARITHMETIC 400

A COMPUTER EDUCATIONAL PROGRAM

Presented By

Laurie Firestein

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ARITHMETIC 400

A COMPUTER EDUCATIONAL PROGRAM

by

Mrs. Laurie Firestein

ARITHMETIC 400 is the first of the next generation of educational programs designed to encourage thinking about arithmetic's problems. Presented in video game format, performance is a measure of correctness, speed, accuracy and fortune as well. Play presents a challenge to young through old alike, to youngsters just learning arithmetic, to those who have not progressed as well as they should, and to those who have developed a reasonable proficiency and wish to polish their skills.

The program, run on an APPLE with 64K, is designed to for use in elementary, junior high and high schools. Little or no supervision is required for play. During the ordinary conduct of the classroom, individual students, depending upon computer availability, can be assigned in turn to solve ARITHMETIC 400's problems.

The program, with emphasis upon bigger numbers, decimal and position, does not fall into one to one correspondence with the traditional classroom. There are important reasons why, which promise to revamp and reshape our education in years to come. And so I would like to start off by reviewing the history of the traditional classroom, stressing those events which have

shaped its structure, showing why it has run its course, and why the time for change is now. Then, after telling you something about the program developed by Dr. Irvin Whiteman, I would like to share with you some of the reactions and accomplishments of my students at Welby Way Elementary School in the Los Angeles Unified School District.

Despite the obvious and understandable absence of supporting documentation, I believe we have no recourse but to go back to the very, very beginning. Even though it is impossible to pinpoint the first awareness, we can be sure that it was tens of thousands of years ago when some men grew sure life on earth was guided by the heavens. When its time came, the idea of a count to bind the seasons to the days, the months, and the years, made sense. And so, as the years passed into centuries, and the hundreds gave way to the thousands, there were more and more numbers of all sizes to remember, to passed on from father to son. Slowly and surely, the great astronomers and astrologers had to move over to make room for the mathematicians who developed the number system which made it possible.

For an oh-so-long time, it seemed to the sages that the creator in his infinite wisdom had structured the passage of the sun around the earth in exactly 360 days and that of the moon in exactly 30, making for a perfect multiple of 12 months in each and every year. Unfortunately for the number rememberers, the seasons did not rotate around so nicely. There was no question about it; there had to be an alternative to mental record keeping and problem solving.

From then on, the pace of significant events quickened exponentially. The relics of inscriptions found in Sumeria date back not much more than

5000 years ago. Paper was invented in China only 2000 years ago. Marco Polo brought some back to Europe just 700 years ago. When Benjamin Franklin was setting up his printing business, it was still in short supply; not that it mattered much with so few who could read, write and do arithmetic. There was little in the way of education, most of which remained a father to son tradition. As far as the simple sums, the proper way for those who could do them, was to think them through to the extent possible, carefully husbanding the use of hard-to-get expensive materials.

Not until the close of the last century, not much more than a hundred years ago, the classroom that you and I know today. And the reasons are clear: The Industrial Revolution had shaped the factories and it was shaping the offices as well. Without its desks, there would be, there could be, no greatness. There had to be a school system to educate a citizenry capable of carrying out arithmetic using paper and pencil.

This was the moment, the turning point, for it was precisely then that the way man had always worked his arithmetic began to change. Rather than a thoughtful process, it started on its movement in the direction of non-remembered numbers transformed by mechanical steps using paper and pencil. And as it did, the mental skills were replaced by motor. From its beginning, the now compulsory classroom stressed penmanship, how to align suitably shaped and proportioned characters, how to set forth problems, carry through the steps of arithmetic, and record answers.

It is not now, nor has it ever been, an easy time. As our society has grown increasingly complex, we have had to cram in more and more early on. The result is a school system which has placed great physical demands upon the

child at a time when his motor skills are only poorly developed. Where possible, of course, accommodations have been made to soften these demands, and so the sequence of teaching we follow in our classrooms today.

The starting place is small, whole numbers of the one and two digit variety confined to addition, and some subtraction with non-negative answers. Division awaits its turn and when it finally comes, not only are the problems small, but the answers are as well. Not until midway through primary school are the decimals included, and not until near completion the negative numbers. Not until then, does the student meet with the number system in its entirety.

During these introductory years, as we all know too well, the child learns calculation, not as a thinking action, but as a reflex. Having the sums simply at his fingertips is not good enough. Taught the general rules of arithmetic, the novice is presented with unending opportunity to exercise them over and over again. The indoctrination is memorization, drill, drill and more drill in the "by rote" classroom.

Unfortunately, but for the notable exception of an elitist minority, the system does not work. The declining scores of the years tell us over and over what all of us deep down know: that there is simply too much variance in the developing mental and physical skills of children; that there is too little middle ground; that there is too much disparity; that there are too few correlations. Some children may lead in both the mental and physical; some may do well in one but not so well in the other; some may lag in both. Those who succeed are only those who do well across the board; the greater number fall further and further behind as the problems grow bigger and bigger.

The problem with the school system is not that we have not been successful in accomplishing what we have set out to do, for, in truth, we have. Our goal has been to teach children how not to have to think about arithmetic, and we have been eminently successful in doing just that. Children, in varying degrees, do learn to solve problems mechanically, following the rules. Unfortunately, when they run into trouble, with nothing to think about, their poorly developed, painfully acquired skills slowly and inexorably crumble away.

In complete contrast, and this is what is so remarkable, the educational program ARITHMETIC 400 avoids the difficulties of the traditional classroom by setting aside its paper and pencil dependency and returning to the arithmetic that always was: numbers to remember and think about. Its starting place is the addition, subtraction, multiplication and division of numbers of all sizes, with and without decimals, both positive and negative as well. Covering so much more material early on without the so-called essential tools, it directs its problem solving not to the small and oftentimes difficult, but to the easy to remember and easy to do. Along the way the player learns to think about problem solving, not through memorization of teacher aphorisms, but through self-discovery.

Working with problem sets marked by patterns, able to simply button out correct answers, the student can search out and uncover pertinent relationships, and having done so, apply them accordingly. Using his computer as a calculator when necessary, the player learns to solve problems, think through solutions, check when in trouble, and learn through his mistakes.

The program can be used in a number of different ways. A lesson can

be specified between any two digits, one through nine, for each of the operations of addition, subtraction, multiplication and division. They vary in difficulty: at the low end, there are addition problems of whole numbers made up of ones and twos, and at the upper, multiplication problems of decimal numbers made up of higher values. Taken together, there are 180 unique lessons so specified. The average time to carry out a single lesson varies between 15 and 25 minutes.

The multiplication screen shown in Figure one consists of sevens and eights in the basic format of nine problems. The cursor is located between the upper two cells of the first column. Moved upward, the first row cell would be initiated; moved downward, the second row. Once triggered, the answer cursor appears automatically within the cell and the answer can be entered through the keyboard. In turn, the cursor can be moved from cell to cell until the screen is completed.

Problems can be solved one at a time, but there is a better strategy. The proper move is to study the screen and determine if there are commonalities among answers. For example, on the screen shown, the answers of the top row are all the same: 56.56. A good move would be to move the cursor to either of the two cells containing three horizontal dots at either side of the first row. When initiated, the answer cursor will automatically appear in each of the three problem cells, and the answer can be entered simultaneously in each. If you note that the answers in the second row are common, that row may be initiated following the same procedure. And if you note that those of the third row are common, you may do so again.

There is good reason for doing so, for there are bonuses associated

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...	$\begin{array}{r} 70 \\ X \ 0.8000 \end{array}$	$\begin{array}{r} 700 \\ X \ 0.0800 \end{array}$	$\begin{array}{r} 0.07 \\ X \ 800.00 \end{array}$	...
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...	$\begin{array}{r} 80 \\ X \ 0.7070 \end{array}$	$\begin{array}{r} 8000 \\ X \ 0.0070 \end{array}$	$\begin{array}{r} 7.0 \\ X \ 8.00 \end{array}$	...
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...	$\begin{array}{r} 0.707 \\ X \ 80.0 \end{array}$	$\begin{array}{r} 70.70 \\ X \ 0.0 \end{array}$	$\begin{array}{r} 7.0700 \\ X \ 8 \end{array}$	...
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SCORE 0

Figure One

with solving problems in groups rather than one a time. There is good reason, also, for noting the number of stars at the bottom of the screen, for the score you get depends upon their number. It pays to think through your play before making it - provided you do not run out of time while doing so.

If you examine the screen carefully, you will note that not only are the answers common to the three rows, but they are common to each other. There are alternative plays. The cursor could be moved to each of the column selectors marked by three vertical dots in the top frame. There are also diagonals with appropriate dots at the far ends of the frame. But for this screen, with all answers the same, the best move of all would have been to either of the two total cells marked by nine dots, yielding the highest bonus of all.

There are two other cells located within the top frame. If the player is not sure of the rules, he can move the cursor to the ? cell to obtain instructions. When the review is completed, the program returns to the screen at the time of the request. If a player is unsure about a problem, the movement of the cursor to the C cell will permit him to use the computer as a calculator.

With a little practice there is little need for these keys. Even the very young catch on quickly and from then on they are on their way. Perhaps the best way of telling you just how much so is to share with you the reactions and accomplishments of some of my students at Welby Way Elementary School. Before doing so, however, I would like to say a few words about other programs we have used. As you know from your own

experiences, most of the published software consists of monitor displayed flashcards embellished by window dressing.

These other programs simply do not compare. The computer is used to present simple elementary problems one by one and little more. Flash cards are not exciting as cards, nor are they anymore so displayed on a screen. Doing the same little problems over and over again has got to rate high on the list of unmitigated bores. And it is easy to see why this gut reaction that you and I share is held by the children as well. After the initial excitement of "Wow, I am going to play with the computer," and "Boy, I want to see what happens when the guy falls off the airplane," interest fades. The problems, like seven plus two, are ones they have done over and over. There are no real challenges. Week in and week out, the games are predictable. With just a little play, the kids want to get on with something else.

That was pretty much our situation until mid January of this year when we obtained our ARITHMETIC 400 program. The difference in reaction was instantaneous and explosive. When children come to the laboratory now, the first thing they ask is whether they can play the "nine cell" game, the name some of them use to call it. And there are a number of good reasons why: For one, none of them have really mastered the game. Another is that with 180 possible different lessons, they have not had sufficient opportunity to work more than a few. And to my mind, most importantly of all, the play is so much like that of a video game that

all want to try to become the champ.

My fifth and sixth graders, especially, go absolutely hogwild trying to get high scores. Not all screens are the same and not all present the same opportunity for high scores. Not everyone is lucky enough to get a screen in which all nine cells are the same with its potential for a fantastic score. If one of the children gets one, then another may scream, "That's not fair. Mine only had two columns and that was all." They know about the patterns, look for them, and try to make the most of them.

In the fifth and sixth grades, the gifted, in particular, simply attack the game. They caught on to its ideas very, very quickly. The little instruction I gave them covered keyboard control of the cursor. They had no problems. Children at that age have pretty well developed motor skills and learn in no time at all. The fact is that they put most adults to shame. After that, I discussed the screen and the importance of the patterns in getting better scores. They caught on to the premiums and bonuses in the time it took to tell them. From then on, they were off on their own.

Obviously, for these youngsters, addition and subtraction have no terrors. Multiplication, of course, and particularly the decimal problems takes some thinking. The problems are bigger than the ones they usually have and require some thought. That doesn't mean they don't know how to do them, but figuring them out at the same time looking for common answers and keeping track of time is a challenge. Division, as you would expect, is the most difficult of all. There is no question about it. There is also

the challenge of working these problems from the unit position, moving from right to left, rather than from left to right.

Because the game presents a challenge doesn't mean the students are not up to it. As I said before, the gifted literally attack the game. Once they get the feel of it, they move right along. Each time they play, they learn more about the game, the arithmetic itself, better able to do more. The game is a challenge. It is fun. It makes them want to do well. Doing the arithmetic is not a chore, something which has to be done, but just steps taken in the play of a game.

In the lower grades of the gifted, the same excitement exists. It goes without saying that it takes somewhat longer for younger students to develop the same motor proficiency. More time is required to develop the essential motor skills for moving the cursor. And, by the same token, more is required to get a feeling for the patterns. Among some of the younger, there is not the same competitive drive as among the older. Some concentrate on looking for different ways of solving the screens, trying to do the best they can; a high score, in and by itself, is not the primary drive. The screen presents a set of problems and they become engrossed trying to solve them.

Among the younger, most of the play is with addition, subtraction and multiplication. They have not had the experience with division that the fifth and sixth graders have. They concentrate, understandably, upon the problem solving they know. But, doing so, they learn much about these operations they didn't know before. Properties they may have some fuzzy feeling for suddenly become alive. For example, when you multiply a

number by another with zeros after it, all that is required, after the main calculation has been carried out, is to add the zeros after the answer. Playing the game, solving many problems at the same time, the ability to call forth properties such as these becomes particularly meaningful. With problems like these to solve, you can literally see them counting zeros.

Some of the younger work at the keyboard with one hand. It takes them longer to find and press the keys. With time, and really not too much, they see the value of using two hands, and, indeed, begin to use both. The facts are that the better scorers are those who are familiar with the keyboard and use it efficiently.

Let me present the other end of the spectrum and tell you something about my experiences with first graders in the remedial lab, children who do not appear to be turned on by math and who are not doing particularly well. These youngsters, because of their age, take the most time to learn the motor skills. Nevertheless, with just a little experience, they get the idea and play the game. Please understand that some of them when they do, do so using their thumb. I am not sure why, but that is what they do. As far as they are concerned, it doesn't make any difference and they are in business.

We started off with a screen in addition, say one and two, and the problems presented were like 101101 plus 202202. I did not leave them to their own devices, but made this opportunity a teaching session. I asked them: "How much is one plus two?" And the answer, of course, was three. I asked them about one and zero, and two and zero, and they had these

answers on the tips of their tongues. From then on, it was just a simple matter to point out that these big problems, problems with six digits, problems they had never seen before, were just collections of little problems they had already learned how to solve.

Once it was established these were facts they knew, the children saw that there was nothing to be afraid of, nothing to be frightened about. The moment they realized that that was all there was to big problem solving - it took maybe four or five seconds at most - they were ready to go. They were excited. They felt they were in the big time. They were working with big numbers, real numbers. Not just single digits, but the real thing. They were ready for action.

Students who before never had any interest, hated math, hated turning the pages, came to life. They were thrilled to be at the computer and wanted to discover more. "Can we go on? Can we do higher numbers?" was the clamor. And we did with lessons which involved addition with three and four, and four and five. It was a thrilling, stimulating experience: the same excitement, the same interest, by children who by the book were supposed to be turned off

In the lower grades the attention of the youngsters was directed to solving individual cells rather than the bonuses of the problem groups. This was challenge enough. Going through the screens, there were problems with decimals. These children, of course, have not been exposed to decimals. "What's that?" was the question. "That's a decimal point," was my answer. My feeling was that it was now my turn. The machine provides answers, and children solving its problems can self discover playing the game.

Nevertheless, I felt that some words were in order for these youngsters who had never been exposed to the concept.

I explained to them the role of the point to the right of the unit position, that the numbers to the right were smaller, and that those to the left were bigger. Then I followed up with some examples. In the case of money, one can count pennies and if one has ten of them, we say ten cents. However, if we talk about a dollar which is made up of 100 cents, then ten cents is just one tenth of a dollar.

Then I went back to the screen and explained that to add two numbers with decimals the decimal points must be lined up. Really, this should not have been anything new since they have already been taught that like positions must be added to like positions. Once they saw what they had to do, there was no problem at all. They were able to solve the problems without any difficulty.

I can't begin to tell you or even fully explain the totality of the impact of what has taken place. Remember that these children I am talking about are children in the first grade remedial lab. These are youngsters behind those moving along at the prescribed rate. These are children who have been exposed to ARITHMETIC 400 for just a short time and are now doing third and fourth grade addition problems, problems with five and six digits, with and without decimals. They are now solving problems which the children they lagged behind cannot. They are, supposedly, disinterested children, and yet they can outperform, in some ways, those who are supposedly not.

Let me tell you another of my experiences with an enriched first grader. Before doing so, however, let me tell you what an enriched first grader is. Typically, this student can count up to more than 30, and, perhaps, even up to one hundred. The reason he is considered enriched is that while the rest of the classroom is trying to figure out what combining means, this youngster possesses some understanding. He may even be able to add one digit to two digits. Whatever skills he possesses, they are, obviously, despite the quality of the name enriched, quite minimal.

The youngster I have in mind is a public school child from a very normal home. He had worked with very small problems only, and never had seen any with more than two digits each. It took him no time at all to learn about the machine and how to use the cursor. He experienced no trouble understanding what had to be done. When he first started to play, since he had already some familiarity with addition, he decided to attack what was for him a real challenge: he decided to do subtraction.

The first screen presented involved negative numbers. He had never seen a negative number before, and when he entered his answers, without the sign, they were, of course, wrong. One of the problems he faced was 2002 take away 3003. He felt he could solve the problem even though the top was smaller than the bottom. What he did was turn them around and subtract, getting 1001. When he entered the answer, without the negative sign, it was marked wrong. Another child, a girl, watching my young man, said: "You can't do that. That's illegal. We are not allowed to switch numbers around just because we feel like doing so."

Be that as it may, as far as my enriched youngster was concerned, that was the only way he could solve the problem. He felt sure of it even though he didn't get the right answer. This was another time in which I felt I had to interact. You can see that the machine is a wonderful teaching tool because it raises meaningful questions in the minds of the students. As I said before, this is not a flash card program. These are real problems, and when the child's interest is piqued by what he is doing, that is exactly the right time to help him along. When I asked the little girl whether anything could be done, she said no. But the little boy would not give up. He was sure there had to be a way.

I asked him if he had ever heard about negative numbers, and, of course, he said no. And so I told him something about them. An example I used was that of the thermometer with some of its degrees below zero. Then I explained the need for placing the negative sign before the answer. My explanation was not a long dissertation about the number line from negative through positive. All that transpired took place in a matter of seconds. He learned what he had to do, and, immediately, he was able to solve the problems.

When he came back the next week, he started off with some addition screens, and then switched over to subtraction. This time, however, instead of the simple little problems of ones and twos, he stepped up to those of eights and nines. He exuded confidence. He was sure even though he had never worked them out before, he would be able to solve them. And he was right. When the screen came on, he solved them all. The short

lesson he had learned made such a deep and lasting impression upon him that it was not one he would quickly forget. What else remains to be said about the wonders of trial and error which has not already been said before.

The bigger problems with five and six digits, with and without decimals, with positive and negative numbers, gave him no problem at all. How fantastic! Keep in mind that this child is a first grader! The other students in his classroom plod mechanically along with single digit addition and he zips by with these full sized, complete problems. Please do not lose sight of the fact that this is not a brilliant child, just an enriched one. I know his I.Q. I know that he was tested for the gifted program and did not make it. He is a wonderful, bright, happy child, who needs and deserves more than doing small, little, simple problems over and over and over again. He was exposed to a computer program which challenged him. He picked up the gauntlet and ran with it.

His experience is not unique. The other students have similar experiences. When they come face to face with an unknown like the decimal or the negative number, they don't turn aside because it is strange. They don't turn off the machine, get up, and walk away. They are curious and want to know. They ask questions and want answers. Children who are normally taciturn, who do not participate in classroom discussion, with a problem set on the screen, with a game on their hands, want to know what to do. They want to play the game, they want to learn about how to solve the problems. They don't balk; they are not afraid. They are willing to experiment and willing to try.

I have children who want to play nothing else but ARITHMETIC 400. They have no interest in the other programs. They want to do more, they want to learn about the other screens. They are excited because they feel that they can do these same problems using paper and pencil. Children go home and show their parents how they can work with decimals. The parents are absolutely incredulous. It is, as if by some miracle, their child, who seemed destined for life in the remedial lab, has come to life and is capable and interested in solving arithmetic's problems. It truly seems unbelievable that so much can happen using a teaching tool like this.

• May I say a little more now about the development of the motor skills. I think that the proper time to start with the computer is in kindergarten. This is the time for the child to learn about the keyboard and the placement of its keys. If not, the consequences are that during the first and second grades, the child has to spend considerable time looking for the keys; his attention is directed to finding the buttons and not the problem at hand.

There is the same problem, much more so, of course, using paper and pencil. During the early grades, while the motor skills are still being developed, the primary concern of the child is focused on forming and aligning the digits correctly. These physical acts demand so much attention that the child loses sight of the problem being solved.

One of the greatest contributions of the computer in my opinion is its ease of operation. The quality of the digits produced is identical for all. There are no longer the same stringent demands about digit formation and

alignment. Using the computer, the child learns to think about arithmetic unshackled by poor motor skills; his mind is free to think about the job at hand. Later on, when his paper and pencil skills have been polished, he can fill in with arithmetic by the rules. Until that time, he can think and self discover. No longer must learning be held up until the body develops. The youngster with poor motor skills need no longer be penalized doing arithmetic because he doesn't write well.

As far as I am concerned, ARITHMETIC 400 is not just a game which can be played by a student by himself; it is a teaching tool as well. It presents an opportunity to teach critical thinking. It presents an opportunity to teach mathematics. Mathematics has so much meaning; it is so important. We want to do more than turn out mathematicians; we want to do more than prepare students so that they can shop at the supermarket. There is more to life than that. If you can think mathematically, if you can think logically, if you can solve problems, you can become a musician, you can become an engineer, you can enter one of the professions. There is so much more than being prepared just enough to pass on to the next grade.

There are many children in our classrooms who would pursue other careers if they were turned on to math only a little bit earlier. Their lives would be completely different. Too often, unfortunately, they simply are not made aware of critical thinking. This program, this wonderful program, gives them this opportunity. It presents a complete picture in the early grades about problems of all sizes and kinds. The introduction

is complete. In the later grades, the child looks for the patterns and relationships and learns to solve problems not just by blindly following the rules. They think about what they see and break down the bigger problem to the more easily dealt with smaller.

All of the children are turned on. You can tell by their questions. Take a moment to think about what that means. In the ordinary day to day classroom, it is only the bright who ask the questions; and it is only they who are truly triggered by the answers. The less bright are passed by: they ask for less, and, sadly enough, their reward is less.

What has been so exciting to me is that in all of my years of teaching I have never had the experience I am now enjoying using the ARITHMETIC 400 program. My children are stimulated; they are having fun. And with my children feeling excited, having fun, and, obviously, learning so much more, I find myself feeling excited, and having fun.